Pisé House at North Walsham. Bernard P. Gaymer, A.R.I.B.A., Architect.

DEPARTMENT OF SCIENTIFIC AND INDUSTRIAL RESEARCH

BUILDING RESEARCH BOARD

SPECIAL REPORT No. 5

BUILDING IN COB AND PISÉ DE TERRE

A COLLECTION OF NOTES FROM VARIOUS SOURCES
ON THE CONSTRUCTION OF EARTH WALLS

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INTRODUCTION

During the last two years some people have made a cult of building in pisé de terre, writing of it with all the enthusiasm of revivalists, and claiming that the solution of our housing problem lies in a return to the methods of our ancestors : others, refusing to admit any good point in any rammed earth system, talk disparagingly of mud walls or castles of sand.

To readers of both sentiments this report will bring comfort, for the gist of the whole matter is that, while two or three inventive men have transformed the mud wall into something quite respectable, yet it cannot be claimed that any considerable urban housing scheme could be satisfactorily carried out in this country in either pisé de terre or clay-lump. Mass cob is out of the question.

The merits of a rammed earth wall are many : the writer, after some years' forced trial of many houses built in materials varying from bamboo and string to old rails and corrugated iron, would for sheer comfort take the palm from brick or stone and give it to either timber or earth. Unfortunately both timber and earth walls usually demand heavy annual expense compared with brick or stone; so they are out of favour, while concrete, which can be the most comfortless of all, is being widely used because it is easily maintained.

This collection of notes, therefore, is not offered as a solution of the housing problem, but as a guide for those who are obliged or pleased, in exceptional circumstances, to make the best of local materials.

The use of chalk is hardly touched on, because this material is dealt with at length in the illustrated report on the Experimental Cottages at Amesbury.* But chalk is perhaps the best of all earths for wall making, either in the disintegrating state as rammed earth or in the rock state, with a small proportion of cement, as concrete. Moreover the "clay-lump" of Norfolk is on analysis found to be almost half chalk.

It should be pointed out that in each instance here recorded there actually were special circumstances influencing the builders : the Simla hydro-electric buildings were to be in positions not easily accessible; Mr. Eshelby built in a devastated area; Captain Monro (at the time a medical missionary) had to make his building funds go as far as possible—after about 20 years he

* Information with regard to the publications referred to in the present report is given in the Bibliography, Appendix II., p. 40.

burnt bricks and rebuilt. There is indeed almost an established principle that when circumstances change for the better earth walls go : even in such a place as Peshawar, where it has long been the custom to build in earth not only houses of all sizes for Indians and Europeans, but fortifications, recent work has been in bricks and mortar, since the Railway made fuel cheap for brick- and lime-burning. That there were special circumstances to force his selection in each instance, however, would not in necessary consequence forbid a builder to rise above his circumstances and to give his earth walls something of the qualities of the more solid materials he could not use. So the question arises, Is any of this new work in rammed earth essentially better than the old ? It is best to let the notes speak for themselves, but it is worthy of attention that Mr. Davidson, Mr. Eshelby, and Mr. Gaymer have, each for himself in a different way, combined pisé de terre with cement concrete. It is probable that in such combination, to the benefit of both materials, lies the future of rammed earth.

There is one other outstanding quality in all the new work reported in these notes : that is, simplicity of appliances and methods.

H. O. Weller.

PART I.—COB

COB WALLS

Probably the earliest form of covering for a human dwelling was wattlework, consisting simply of interwoven branches and twigs with the leaves on. This was improved in prehistoric times by covering with earth, clay, or some other adhesive material, and the process became known in England as "daubing," and the construction as "wattle and daub." Such a primitive method must have entailed constant need of repair.

Later, when a timber frame formed the skeleton of the habitation, clay and sticks were used as a filling between the framing, and this was covered on both sides by a plaster formed from lime or clay or both, and sand with broken and pounded tiles. A sounder external wall, weatherproof and capable of resisting extremes of temperature, was obtained.

Bankart, in his "Art of the Plasterer," describes wattle and daub as follows :—

> ". . . Clay mixed with short straw and chalk was then worked in between the main timbers, thus covering the hurdle-like lathing with a rough 'daub' cement.
>
> "Whilst still the clay was wet it was scored over to give keying to the finishing coat of lime plaster, which was itself coloured and often painted with decorative designs on the inner surface."

In half-timber work the panels were filled with whatever material was handiest; sometimes brick, but more often hazel twigs were criss-crossed to form a centre and then covered with daub, the composition of which varied with the materials available. The wattlework of the filling sometimes consisted of ashpoles about as thick as one's wrist wedged in upright between the horizontal timbers and interlaced with thin laths to give a key for the daub. The daub was scratched on the surface to form a key and often floated with the merest skin of plaster as better able than the clay to resist the rain and wind. Clay, however, had its own use and it is doubtful whether anything better could be devised for filling in timber framed houses. It is more than possible that the brick filling in many old examples is a much later alteration. A weatherproof joint between the timber and the brickwork was difficult to obtain, but with a clay filling as soon as wet entered the clay swelled and closed up the joint.

Wattle and daub has many other appellations. In Lincolnshire it is known as "daub and stower" or "stud and mud," in the North Country, as "rice and stower," and as "raddle and daub" or "red and dab" in Lancashire and Cheshire. A "raddis" chimney in Kent consists of "wattle and daub." In Newcastle-on-Tyne the ancient fraternity of bricklayers were styled "catters and daubers." "Cats" were

pieces of clay and straw worked together into fairly large rolls and laid between wooden posts at intervals. "Red and dab" refers also to a special method in which the mud was laid *between* two layers of wattlework.

The ancient round houses of Ireland were made by making two basketlike cylinders, one within the other, and about a foot apart, and packing the mud between them. The creel houses of many Highland gentlemen in the last century were made in this way, except that they were not round on plan.

In John Cordeaux's description of the erection of "stud and mud" cottages in Lincolnshire he says the walls were formed by driving in long rows of stakes and then trampling in with the feet, between the stakes, wrought clay mixed with chopped straw.

The natural clay between the wattlework would show by the solidity of the matured filling that the wattlework was not a necessity and thus would be developed cob walls, once so widespread over the British Isles.

"Cob," in the Century Dictionary, is described as "a compost of puddled clay and straw, or straw, lime and earth," and in R. Carew's "Survey of Cornwall" we are informed "The poor cottager contenteth himself with cob for his walls." "Clom," "clob," and "korb" are older forms of the word and the last points in favour of a wattlework origin, as "korb" means basketwork. "Clob" and "cleam" are forms of widespread Teutonic words for smearing on and plastering.

In a letter to "Country Life" (Nov. 22nd 1913), Mr. Norman Jewson described the traditional way of making and using the cob as follows :—

> ". . . The cob is made by mixing clay and straw with sufficient water to get it to the right consistency. It is generally mixed at the edge of a pond, a horse being used to tread the clay and straw together. A course about a foot high is then laid on the top of the base wall and well trodden down, beginning at one corner of the building and following right round, so that by the time this is finished the cob first laid is hard enough to receive the next course and so on . . . after the wall is brought up to the desired height the surface is pared off and generally plastered . . . ."

He also remarks that,

> ". . . . With reference to cob cottages, which are well known to be comfortable to live in and the materials for building which are so generally abundant, I believe there are very few men to be found nowadays who will build them as cob-building is hard work and messy. . . "

In Loudon's "Encyclopædia of Architecture" there is a description of cob construction in which it is stated that "the more loamy the clay the more suitable," and that "the solidity of cob walls depends much on their not being hurried in the process of making." Loudon also described the first layer or

"raise" of cob on the base wall as being from three to five feet high, the other layers being diminished.

According to a letter from Mr. Tuycross in "Country Life" (14th March 1914), the town of Naseby until the year 1850 consisted almost entirely of mud buildings, and at the time of writing garden and field walls were still occasionally erected in mud in the district. He mentioned that the method of procedure was similar to that used in Nigeria for mud huts. The walls were considered to stand better if rough dressed on the outside with small gravel and mortar, but this was not necessary, and there were numerous good garden and stable walls in Naseby not protected at all on face. The workman put the mud on in layers about six inches thick and then, standing on the top of each layer as he built the wall, beat it firm with a sort of fork, walking backwards along the wall as he did so. Each layer was left for some hours to harden before the next layer was put on. Mr. Tuycross lamented the fact that there are few men left who can do this "mud-walling," and remarked that "houses can only be built where you have the right sort of tenacious mud."

There is evidence that the walls of mud-built cottages in the New Forest were formed of clay mixed with chopped straw or stones packed down between boards or hurdles, these latter being removed when the clay dried and hardened.

In 1809 in Leicestershire, road-scrapings "tempered" with straw or stubble were considered to make the best "mud" for cottage walls, and in the middle of the last century, about Hanbury, the men who worked on the roads built their own cottages of road-scrapings, layer by layer and "when these were set it was impossible to pick the walls down."

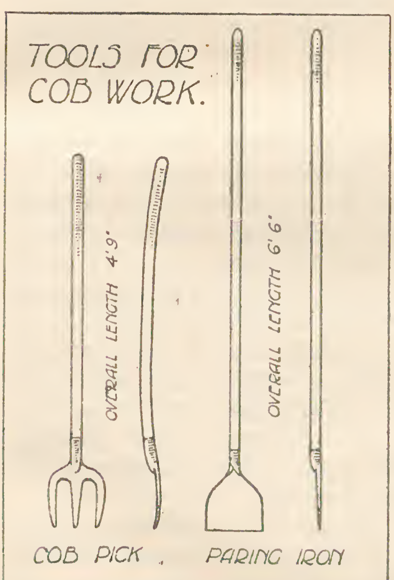

Fig. 1.

Varying in detail in different parts of the country, the general procedure for constructing cob walls may be set down as follows. A plinth wall about two feet thick was constructed of brick, stone or flint according to the materials available. One man stood on the wall to receive the cob which was pitched up to him by another below, the man on the wall arranging it in diagonal layers and treading it down. The first course was laid to project about $1\frac{1}{2}''$ over the face of the plinth wall. Each course was pared down before the next was proceeded with, or else the wall was completed and pared down when dry. The "cob-parer" resembled a baker's peel. (*See* Fig. 1.) Lintels were put in as

the work proceeded and bedded on cross-pieces. Openings were sometimes allowed for during construction; more often they were cut out after the work had settled. Outer walls were often left several months before plastering and the plastering was usually covered with a whitewash of lime and rough cast known in Devon as "slap-dash." Fireplaces and chimney stacks were built in brick or stone.

Where there was chalk, as in Hampshire and some parts of Dorset, it was mixed in the cob to advantage. In 1810 the composition of Hampshire cob was given by Charles Vancouver as three parts of chalk to one of clay, well kneaded and mixed together with straw. Where chalk was not easily obtainable it was only used for the finishing coat after being ground in a circular trough, and cowdung was sometimes substituted in the mixture. A description of the "Winterslow" method of making chalk-mud walls is given in the Department's report on the Amesbury Experimental Cottages by Mr. W. R. Jaggard, F.R.I.B.A.

In sandy and heathy districts of Dorset, loam, gravel and sand were used with heather as a binding material, but such cob was not so durable as that composed of chalk.

In Cornwall, cob was composed of two loads of clay to one of shilf, that is, broken slate in small pieces, barley straw being added as reinforcement.

An analysis of a piece of typical Devon cob for Mr. A. Alban H. Scott gave the composition as—

	Per cent.
Stones (residue on 7 × 7 mesh sieve) - -	24·40
Sand, Coarse (residue on 50 × 50 mesh sieve)	19·70
Sand, Fine (through 50 × 50 mesh sieve) -	32·50
Clay - - - - - - - - -	20·60
Straw - - - - - - - - -	1·25
Water, &c. - - - - - - - -	1·55
	100·00

In many counties where stone is almost as plentiful as soil, cob walls are found in abundance, probably because of its cheapness : a man could construct his own house with his own hands without paying for skilled labour to work material. In South Pembroke cottages were built of cob forty years ago. The walls of some parsonages in the stoney county of Cumberland were made of clay in the seventeenth century, and in Cornwall cob was used equally with the rough granites of the district until quite recently.

Cob is very durable when well protected from wet; more particularly from above and below. With good projecting eaves and a dry plinth wall it forms a dry, healthy, and comfortable dwelling, the thickness and non-conducting properties of the walls preserving a mean temperature within.

Some cob undoubtedly scaled off and bulged when the whitewash or plaster with which it was usually coated became decayed. The walls had a tendency to crack at the angles and the corners were sometimes rounded to avoid this. It was impossible to

repair failures in cob with mud, and bricks or other materials were employed to the detriment of the appearance of the wall.

Excellent examples of cob building can still be seen in the West of England, and in the middle of the last century in Devonshire there were cob houses in perfect preservation which had been built in the reign of Elizabeth.

Comparing the merits of various forms of cottage construction on his estate, Lord Portman, in a letter to "Country Life" (17th January 1913), placed the cob cottage second only to one with hollow brick walls and as superior to those of brick and flint, timber and concrete.

In South Africa in parts now under British rule, natives still erect their single-roomed huts of mud. The mud known as "dagga" can generally be found close at hand. Not all earth is suitable. If it is too "fat," that is, contains too much clay, it tends to crack on drying. It is worked up with water, and possibly straw or grass, and bricks are moulded about $15'' \times 9'' \times 4\frac{1}{2}''$. These are sun-dried and used on edge. They are known as "green bricks." The mortar used is dagga itself. This is also used as mortar for walls of burnt brick and for interior plastering, for which purpose it gives a rough surface similar to a second coat. Paper-hanging on this is somewhat difficult to carry out if tried by a decorator used to our plaster walls, otherwise it is done quite readily and well. The roofs are often of corrugated iron or sheet tin (from kerosene tins). The eaves overhang a little. The walls seem to stand the heavy rains quite well. Floors are made from ant-hills crushed and mixed with water, and painted over with bullock's blood, which gives them a hard shiny surface, brown in colour.

In New South Wales settlers at Mildura thirty years ago built their houses of sun-dried mud blocks. The mud was mixed by a series of blades fixed to a central pole capable of rotating at the centre of a shallow circular hole in which the mud and water were placed. The outer surface of the finished wall was sometimes painted over with several coats of oil.

The employment of cob in moulded blocks, certainly the most convenient way of using it, was common in the East of England, and known as "clay-lump" work.

Notes on Suggested Improvements in Cob Buildings

In taking up the question of the revival of cob as a building material, it will be obvious that there are a number of essential points in which the revived cob should more nearly approach present day standards of construction than the older type of cob was apparently capable of doing.

The idea generally held regarding the preparation of cob is that almost without exception it was prepared from a clay soil and worked to a suitable consistency with straw and water. There is plenty of evidence that there was considerable variety in the materials used.

From a recent investigation it would appear that several of these materials would require quite different treatments to produce satisfactory cob. The point to be noted here, however, is that it is not possible, from the scattered and in most places vague descriptions available, to set out in detail the various treatments adopted with the different materials.

Generally, the body of the cob was obtained from earth on or near the site of the building. The method of treating the soil or sub-soil used would usually be strictly local, as the small area over which the cob builder would operate would not generally bring him into localities where the soil was of a different geological character and required a different treatment.

Considered in the light of present-day conditions of labour, it is likely that the old-fashioned method of preparing and building cob would be looked upon as "messy," clumsy and crude and that none but the very lowest grade of labour could be expected to carry it out.

There is evidence that the cob-builder was looked upon as a skilled man in ancient times. For example, the men who worked in cob were known in Devonshire as "cob masons." But it is probable that these men, while chiefly responsible, had the heavy and cruder part of the work done by unskilled or semi-skilled labour. In comparison, however, with such trades as that of the mason and the carpenter, the number of skilled men engaged in cob-building was probably never great, nor was the method ever developed so as to require a very high degree of ability in execution.

As with other methods of building used in ancient times, the long time taken in the erection of cob-building was not considered a serious disadvantage. Two years was stated to be the time necessary to erect a house of two floors.

To some extent the time taken would vary with the materials used and the method of erection adopted. For example, the method of preparing "clay lumps" or "green bricks" to be built up into a wall, would undoubtedly be speedier than the method of throwing the cob on to the wall, treading and beating it down and paring the face to a suitable finish.

It is obvious, that, whatever the method adopted, considerable time had to be allowed for the material to mature, so that all shrinkage and settlement might be completed before the work of finishing the interior and exterior surface coverings and adding the fittings could be proceeded with.

The outstanding fact to be noted in reference to cob buildings is the frequent reference to their comfort. From this we may infer that the temperature was equable, warm in winter, cool in summer, and that the cob was able to resist the penetration of damp from without. These characteristics were probably in large measure due to the great thickness of the walls.

Trouble seems to have been experienced in some cases by dampness, caused either by leakage into the top of the wall, or by a capillary attraction, from moist foundation. No cob build-

ing was able to stand floods, and there are frequent references to their complete collapse when flood waters mounted up the walls.

Regarding the strength of the cob, its limitations were such that there is no attempt on record to construct a more ambitious cob building than a two-storey cottage.

It has not been possible to obtain any data regarding the cost of cob walls as erected in ancient times, certainly not such as to be of value at the present day. It is certain that, wherever houses were to be erected, cob-building was selected where cheapness and ease of erection were essential factors in the undertaking. It is probable that the method would be relatively cheaper than brick or stone to-day.

Among the chief advantages to be gained from a revival of cob-building at the present time are :—(1) The cost of the raw material would be low and the amount of transport required small, since materials would be obtained on or near the site of the proposed building.

(2) No demand would be made upon an already restricted fuel supply, no artificial heat being required in the preparation of the cob.

(3) No mechanical power or heavy and elaborate machinery would be required in its manufacture.

(4) The amount of skilled labour required would probably be small, and unskilled labour could readily be trained to carry out the work successfully.

In attempting to produce an improved cob, these advantages must, so far as is possible, be retained.

It will be apparent, from what has been stated earlier in these notes, that unless the use of cob is to be limited to those localities where some kind of tenacious earth is found, means will have to be devised for treating a large variety of earths, so as to produce a more or less uniform cob. Assuming that surface formations only are to be used, the materials available would be obtained from the soils commonly found and roughly classified as :—clay soils, sandy soils, calcareous soils, gravelly soils, loam and peat. Whether all of these soils could be worked up into cob is not yet apparent.

Where pure sand or gravel is found in abundance, it would probably be as economical to work it up into some form of concrete with cement or lime as to attempt to obtain consolidation with a material so devoid of natural cohesion by mixing with other earths.

The transportation, except over very small distances, of either the raw material or the prepared cob, would usually add so greatly to the cost that where the soil was unsuitable or insufficient, other methods of construction would have to be adopted.

If it be assumed that the form of cob most likely to be revived is that in which the " green bricks " or " clay lumps " are used, the question at once arises whether there might not be great improvements in the production of cob blocks by introducing some of the mechanical methods adopted in preparing and

compressing the materials used in brick-making and coal or peat briquetting.

The high initial cost, the heavy weight and large power required are points seriously against such methods being adopted. By keeping the blocks small and devising some form of portable machine, capable of carrying out all the operations required, something might, however, be accomplished along these lines, especially where the number of houses to be erected justified the initial expenditure required.

In the absence of such mechanical assistance the blocks would have to depend for their solidity and strength upon some form of physical or chemical bond, which did not require much pressure to bring it into action. Sufficient has been said to make it apparent that the labour necessary in mixing and moulding the cob blocks, being largely of a repetition character, might be classed as semi-skilled, so that there need not be any serious call upon the market for skilled workmen.

If, with every possible improvement, cob-building is to be a considerably slower process than building in brick or stone, it will greatly hinder its adoption under present conditions. There is evidence, however, that if the work can be carefully planned and groups of houses proceeded with together, the length of time taken need not, on the whole, be much longer than for houses built in other materials. The time taken to prepare cob bricks may possibly be shortened so as not to exceed greatly that required for preparing burnt bricks (including the getting and tempering of the clay). Much will depend on the methods adopted for preparing the cob.

The weight of cob would usually average less than that of clay, but as a basis of calculation we may assume a density of 120 lbs. per cubic foot. A wall ten feet high would thus by its own weight induce a maximum stress of 1,200 lbs. or, say, $\frac{1}{2}$ ton per square foot at its base (approx. 8 lbs. per square inch). Dealing, as a maximum, with the case of a two-storeyed house and taking the wall to be 20 ft. high if the ground floor is laid solid on the site, we have only to allow for the weight of the first floor and the roof. Very roughly the average floor, with full dead loading, and roof may be taken as equivalent to a further height of five feet and two feet of cob one foot thick, respectively. We have thus to allow for an equivalent total height of cob wall of 27 ft. This assumes a wall one foot thick; thicker walls would reduce the stresses somewhat. This produces at the base a stress of about $1\frac{1}{2}$ tons per square foot (approx. 23 lbs. per square inch). To give a factor of safety of five we ought, therefore, to have a maximum compressive strength of at least $7\frac{1}{2}$ tons.

As failure in the material will most probably be by shear and the shear stress induced will be half the compressive stress induced by any load, then the maximum shear strength ought to be $3\frac{3}{4}$ tons per square foot. As the shear strength will most likely be much less than half the compressive strength, it is probable that a maximum compressive strength of 10 to 12 tons per square

foot (160 to 192 lbs. per square inch) will have to be obtained; that is, a wall equal in strength to one of common bricks in lime mortar.

In no case in actual construction need the cob be called upon to resist tensile strains, but if the cob-block method of construction is used the under surface of the blocks will be in tension when being lifted to be placed in position. Immediately after moulding and while hardening they can be supported on wooden pallets of a suitable type. As, however, the maximum static tensile stress for such a large block as $18'' \times 9'' \times 6''$ is only 2·81 lbs. per square inch, it is probable that this could be met. The blocks would, however, require careful handling.

Improvements in strength might be obtained by:—(*a*) Mechanical Compression, (*b*) Reinforcements.

Reductions in maximum loading might be obtained by:—

(*a*) Building only one-storeyed houses.

(*b*) Reducing the thickness of the upper storey walls to a minimum or by the use of dormer windows.

(*c*) Using the cob only as a filling to a weight carrying frame.

(*d*) Constructing the upper storey of timber framing faced with tiles or rough cast.

Assuming that properly consolidated cob can be produced, it would appear that, given sufficient thickness, it will prove fairly impervious to moisture and sufficiently non-conducting both as regards heat and sound.

The addition of an impervious outer coat may be accomplished in several ways:—

(*a*) Some form of plaster or cement coating laid direct on the cob;

(*b*) The plaster or cement coat may be laid on expanded metal or wire netting, secured sufficiently far from the face of the cob to ensure a key for the plaster, but at the same time close enough to allow of the space behind the metal being filled up;

(*c*) By using some form of thin plaster, asbestos or concrete slab secured direct to the cob or to creosoted wood fixing strips built into the joints.

For the exterior surface, method (*b*) will probably prove most satisfactory, as the facing material will obtain a good key independent of the cob.

For interior walls method (*c*) might be used, when three-ply boards would also be available. The cob itself would probably not be sufficiently hard to be left as a surface finish on interior walls except above dado level.

Regarding (*a*) some experience would be necessary before a decision as to its reliability could be arrived at.

The chief points to be considered, to ensure that cob construction might be sufficiently durable for ordinary house construction,

say to last 60 to 100 years without requiring heavy outlay on upkeep are :—

(*a*) Protection from moisture.

(*b*) Protection from vermin.

(*c*) Protection from surface wear, weathering or destruction by occupants.

(*d*) Protection from chemical or physical decay.

Protection as in (*a*) and (*b*) would be more or less ensured by adopting the methods suggested for obtaining an impervious covering. It remains, however, to deal with the question of dampness arising from leakage into the top of the wall and moisture drawn by capillary attraction from the foundations. As dryness is so essential to the life of a cob wall, it might be advisable to place some form of simple damp-proof courses immediately beneath the roof timbers. Regarding damp arising from the foundations, it would appear that all such trouble could be avoided by carrying the foundation construction up to a height of nine inches or 1 foot above ground level, the cob walling to start from this level. The foundations could be of stone or brick in cement mortar or of concrete. Such a method would be simple and efficient, especially if the ground floor slab of concrete were incorporated with the foundations, wood constructed ground floors being discarded. Protection from the inroads of mice and rats ought not to be difficult if the methods of construction already suggested are adopted. This point should, however, be carefully kept in mind in designing. Additional protection might be afforded by incorporating some form of vermin poison in the cob, but this might prove objectionable to the persons manufacturing the cob.

Chemical or physical decay may take a long time to develop, but cob as made up in the past has not, so far as can be ascertained at present, shown any such defects. It is possible, however, that if other methods of preparation and consolidation are used, involving in some cases chemical action, inorganic or organic substances might be formed in the cob, which, with the lapse of time, might develop in such a way as either to make the cob objectionable, for example efflorescence, or destroy the cohesion of the cob and render the building unsafe. Only by the exercise of extreme care and the utilisation of all possible tests can such dangers be avoided. Next to strength, the character of permanency is most essential.

The adoption of cob-building with pre-made blocks would necessitate a careful consideration of the size and weight of same in order to ensure an easily bonded and easily handled unit of construction. Some sizes and approximate weights are given below :

Brick.	Weight.
3″ × 6″ × 12″	15 lbs.
$4\frac{1}{2}$″ × 6″ × 12″	$22\frac{1}{2}$,,
6″ × 6″ × 12″	30 ,,
$4\frac{1}{2}$″ × 9″ × 18″	50 ,,
6″ × 9″ × 18″	68 ,,

The cementing material between the blocks should consist of some specially prepared cob, plastic, adherent, and quick-drying in character.

By the use of cob bricks openings could be formed as the work proceeded. The old-fashioned method, of cutting the openings out after the walls had hardened, would be too slow and clumsy for modern use. Concrete lintels, with a bearing of at least 18 inches on each side, should prove satisfactory. All external angles to doors, windows, &c., should be rounded to a radius of at least 3 inches; this would give greater solidity and permanence, and at the same time be cheaper, than the use of angle beads. No framings should be fixed in any openings until the walls had had time to settle and dry. Reinforced concrete frames would probably prove more satisfactory than timber frames, as the latter would be specially liable to decay with cob walls unless special precautions were taken to see that the walls were thoroughly dry before fixing.

Chimney stacks in cob have been satisfactorily erected and the flues constructed of 6″ or 9″ drain pipes, built up as required and closely surrounded by the cob. The heat may prove to have a destructive effect on the cohesion of the cob, but provided the thickness of the cob is sufficient this effect could be limited to the few inches immediately surrounding the flue pipes.

One great difficulty to be faced in re-introducing cob-building is, that at present no existing building byelaws would allow such a material to be used. Such restrictions, however, would not apparently apply to outhouses and boundary walls. There does not, therefore, appear to be any reason why the use of this form of construction should not be encouraged for such erections. By this means a great deal of experience might be accumulated which would prove of great value in the further development of the method.

Summarised, the following are the chief standards and improvements to be aimed at :—

(1) The method of building by cob blocks to be adopted.

(2) The blocks to be :—

- (*a*) Not too heavy.
- (*b*) Strong enough to bear all ordinary handling.
- (*c*) Capable of drying quickly and uniformly.
- (*d*) Of a compressive strength not less than 7½ tons per square foot (but higher if the material is not capable of withstanding the equivalent shear strength).
- (*e*) Free from all liability to chemical or physical decay.

(3) The raw materials to be such as may easily be found near the site of the building.

(4) A minimum of mechanical power to be required in manufacturing cob.

(5) The cost to show a very considerable reduction as compared with brickwork in the same locality.

(6) The durability to be such as to ensure a life of at least 60 years without unusual expenditure on upkeep.

CLAY-LUMP BUILDING IN NORFOLK

Building in clay-lump in England seems for some undiscoverable reason to have been confined in the past to East Anglia. For the purpose of an inspection of old and new examples of this work the villages of Tottington, Watton, Harling and Gorboldisham, all in the neighbourhood of Thetford, were visited. At Watton, Harling and Gorboldisham, houses of clay-lump were being erected from the designs of Mr. G. J. Skipper, F.R.I.B.A., of Norwich. The clay lumps for these cottages were prepared by the traditional method.

Making of Clay Lumps

Clay-lump could be reasonably termed "cob-lump," for the preparation of the clay before being moulded is in all respects similar to that for the cob of some districts. The clay is dug on or as near the site as possible and placed in the form of a circular "bed." The large stones are picked out and water and straw or sedge and twitch grass added. The straw or sedge is cut to lengths of about 9″. The mixture is turned over with a rake with four long prongs and "trodden," usually by a horse. The "treading" is continued till the straw is properly distributed and the clay of even consistency and sufficiently plastic. It is then placed in a bottomless wood mould (Fig. 3) and the top levelled by skimming with a board. The mould is lifted off as soon as the lump is sufficiently set to retain its shape. The lumps are left to dry in the open, sometimes in stacks, protected of course during heavy rain by a covering of straw or tarpaulin. The most usual dimensions are 18″ × 9″ × 9″ and 18″ × 9″ × 6″ for large lumps, and 18″ × 6″ × 6″ for small lumps.

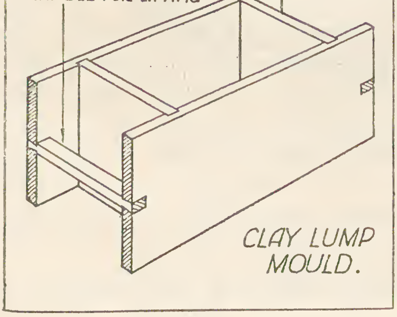

Fig. 3.

There are some users of clay lumps who contend that they should be made one year and used the next, but in the new houses they are being used after one month's weathering. The lumps used in the workshop at Harling, described later, were not even perfectly dry when they were built in, and this workshop is undoubtedly one of the most remarkably satisfactory pieces of clay-lump construction in the neighbourhood.

Fig. 2.—Old Cob Cottages in Devonshire.

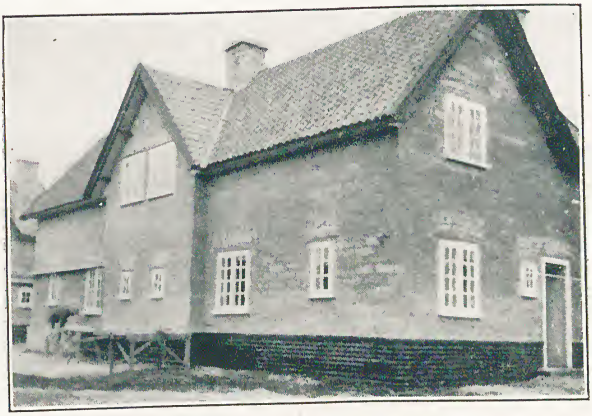

Fig. 4.—Clay Lump Cottages, Watton. G. J. Skipper, F.R.I.B.A., Architect.

Old Work

In the before-mentioned villages clay-lump construction is very much in evidence. In a few cases no attempt has been made to cover the lumps, and they are exposed to the weather. However the large majority possess a protective covering of some sort; lime plaster, tar, or a thin facing of brickwork.

At Tottington there is a farm-house, probably about 200 years old, with one wing of stud-work and lath and plaster and the other of clay-lump covered with plaster. The whole house is in a poor state of repair and the plaster has fallen away from the lumps, leaving them exposed. The walling appears quite sound. The outbuildings of this farm are of clay-lump and the barn of "forked clay" or cob. The lumps have no protective covering and are crumbling badly. They appear to have been made from extremely poor clay of sandy formation. The cob walls of the barn are 13″ thick and almost 16 ft. high. The barn is about 50 ft. by 20 ft. The external plaster has fallen from the walls, but, except where water has penetrated from the top through the dilapidated condition of the roof, they are still perfectly sound and vertical. Near this farm are some cottages with stabling constructed nearly 30 years ago of clay-lump, without covering. Here again the same poor clay has been used, but the walls are fairly sound.

In Harling there is a row of old cottages of clay-lump with the covering plaster panelled out, and adjoining these, at one end, is a stable building with the lumps exposed. These show some signs of having once been covered with a wash of some sort, but this has been gone for years and the blocks still present an undamaged surface.

The Council School in Harling, once the Corn Hall, is about 100 years old and, thanks probably to having had its protective coat kept in good repair throughout, is still an excellent example of a sound, dry, clay-lump building.

The workshop in Harling already referred to was built over 20 years ago. It is a tractor repair shop, roughly about 130 by 25 ft., and contains one shop about 70 ft. by 25 ft., so there is 70 ft. of clay-lump wall without tie-walls. The external walls are about 16 ft. high on a brick base and only 12″ thick. The internal partition walls, also of clay-lump, are 9″ thick. The only brick wall in the building is 9″ thick and faces to the road. This wall has had to be painted, as it was found to be damp. The clay-lump walls are tarred externally. The whole building has successfully withstood a good deal of vibration from heavy tractors. The walls carry wood king-post trusses and guide rails for two pairs of large sliding doors and two pairs of small doors.

I was told that there are some very satisfactory cottages from 30 to 40 years old on Sir Hugh Beevor's estate a few miles from Harling. These I did not see. It is interesting to note that tenants of these cottages are in no circumstances allowed to drive

nails into the clay-lump walls or allow creeper and such like to grow upon the exterior.

The inhabitants of these dwellings say that, in spite of the fact that the walls are comparatively thin, their houses are cool in summer and warm in winter, and also that they are perfectly dry.

It was usual to commence the clay-lump walling from a brick base from 18″ to 24″ above ground level, and it is noticeable that where this was not done the wall has suffered in consequence from damp and the inroads of vermin. The clay lumps were bedded with clay mortar in a semi-liquid state.

There does not seem to be much doubt that the chief difficulty that clay-lump builders have had to contend with all along is that of obtaining a lasting protective coating for their walls. Lime plaster was only satisfactory so long as it was kept in good repair and this repair resulted in patching and consequent unsightliness. The tendency seems to be for all such renderings to fall away in slabs for want of a good key. I could find no evidence of wire-netting having been used as it sometimes is in cob walls for reinforcing the rendered coat, but in some parts of Norfolk I believe it was the custom to fix lathing to the clay before plastering. It was probably this difficulty of obtaining a durable rendering that induced so many builders in clay-lump to go as far as encasing with brickwork. The neatest and best preserved cottages are those with their external walls tarred. In some cases sand was thrown on to the tar whilst wet and the walls finished with colour wash. There are certainly examples to be seen where the surface of the clay lumps remains as hard as ever although fully exposed to the weather, and some of the unfinished walls of the new cottages being erected, although adequately protected from damp at the top, have been exposed otherwise for some months without apparent damage.

New Work

The clay lumps for the new houses were prepared as described and the general construction adheres more or less to local tradition. The lumps at Watton and Harling are bedded in clay mortar, but at Gorboldisham lime mortar is used. The lump walls stand on a brick wall about 2 ft. high. The external walls are 9″ thick and made with 18″ × 9″ × 9″ or 18″ × 9″ × 6″ lumps and the internal partitions are of 18″ × 6″ × 6″ lumps. The whole of the walling and chimney breasts are in clay with the exception of course of the plinth wall, and of the fireplace jambs and arches in the Gorboldisham houses. The chimney stacks above roof level are in brickwork. Tarred wood lintels with a good bearing and a rough brick relieving arch above occur over windows and door openings (Fig. 4). Internal projecting angles are finished before plastering with cement.

The walls are the same thickness throughout their height and this necessitates the floor joists being built into them. The windows are of the ordinary cottage wood casement type. Such

finishings as skirtings and jamb linings are nailed straight through to the clay lump, which holds them like a breeze block. Immediately above the ground floor windows a projecting weather board is provided, and this runs right round the house supported on wood brackets spiked to the walls. The roofs are of the ordinary type and covered with pantiles.

The internal plastering at Watton was completed. The walls were smeared with a coat of clay plaster and while still wet a lime sand coat was added. This is covered with a finishing coat. Lime is sometimes mixed with the clay plaster to form the first coat. At Gorboldisham where lime mortar had been used for jointing it was intended to lime plaster straight on to the lump. The brick plinth walls were being tarred and at Watton the protective covering, in the form of cement rendering, finished with rough cast was being applied (Fig. 5). Broad headed galvanised nails were driven into the clay-lump at frequent intervals to key the rendering.

Where gables occurred they were to be filled in with elm boarding above the weather board over the first floor window.

General

I was informed by Colonel Mornemont, of E. Harling, Chairman of the Housing Committee, Thetford R.D.C., that the cost of the clay lumps made from clay dug, on or near the site, weathered, and ready for laying worked out at 20*l.* per 1,000 for blocks 18″ × 9″ × 9″ and about 15*l.* per 1,000 for the smaller ones, 18″ × 6″ × 6″. A large lump 18″ × 9″ × 9″ substitutes 12 bricks, so the cost of the material to build a piece of wall in clay-lump that would take 1,000 bricks is about 34*s*. A builder at Watton estimated that a man and a boy could lay in plain walling upwards of 300 18″ × 9″ × 6″ lumps per day or the equivalent of 2,400 bricks. Highly skilled labour is not required.

It seems no attempt is made as a rule to obtain a better mixture for the lumps by adding desirable ingredients of which the clay when dug is deficient. A clay was preferred, according to the builder, with a low content of sand. The clay in the Thetford district appears to contain a very high percentage of chalk. That used for the new houses at Gorboldisham has resulted in a lump of much coarser texture than was obtained at Watton and Harling. The surface of the coarse lump will afford a better ground for rendering.

As far as strength is concerned there does not seem to be much doubt that clay-lump will do all that is reasonably required of it. Like other earth material walling, unless protected from wet above and below it will fail, but given a plinth wall, damp course, and overhanging eaves, and additional protective surface coating, it is undeniably remarkably durable. The coating is the difficulty; even if not necessary, it is desirable, in order to hide the ugliness of the clay-lumps. After a few years, the cost of keeping this coating in repair would probably wipe

out the initial saving over brickwork, but against this there is the fact that the clay-lump house is a much more comfortable dwelling than its thin-walled brick rival.

6th June 1921. P. W. B.

MUD WALLS IN BENGAL

There are two kinds of house with which I have had to do, the ordinary mud house of the Bengali peasant, and the improved variety, which is more or less an invention of my own. The ordinary mud house is small and generally consists of only one room with verandahs on one, two or three sides.

The earth should be clay and sand mixed. I doubt if the ordinary "ghorami," or house-builder has any ideas as to proportions, but pure clay cracks when dry and pure sand washes away in rain, hence a sandy clay is the best.

The earth, having been dug from a suitable spot—in the ordinary villager's case, close to the site of house, where an excellent breeding pool for mosquitoes is thus formed—is brought to the site of the house, water is poured on it and it is then trodden by men into a suitable sticky mud. On no account must it be the least liquid.

A shallow foundation is dug for the wall, generally about six inches deep, and then a man with two chops of a kodal, a large hoe with a short handle parallel to the blade, picks up a lump of mud, tosses it to another man who tosses it to the actual builder, who then by hand with a piece of bamboo, slaps, pushes and kneads it into the wall (Fig. 6). A layer of about 1 foot in height and, if I remember rightly, about 18″ in breadth is built and allowed to dry. The thickness of the wall diminishes slightly with height, but I never saw any of these men use a plumb-line.

lustration
missing

In buildings which were larger, bungalows for Europeans, hospitals, &c., I first built a brick plinth, to about 1 foot above ground level. Above the plinth were two courses of brick and then a damp-proof layer of asphalt. On this wall of 20″ in breadth was built the mud wall as above.

These houses all had verandahs on four sides to protect the walls. The two courses of brick referred to prevented the base of the wall being cut away by driving rain.

We never tried glass in the walls to stop rats—I doubt if we could have got enough glass—but on top of the wall was a layer of fairly thick Willesden paper, which effectually kept white ants out of the thatch for years. So far as I know, no rats went through it either, but they climbed up the verandah supports and gambolled on the ceiling cloth with great vigour.

The thatches were simply laid on the wall; their weight—and the verandahs, plus some iron rods bolted into the ground—kept them in position, even in the great 1909 cyclone.

The walls were first allowed to dry thoroughly and were then plastered with a mixture of liquid mud and cowdung; but when

smoothed with a trowel it looked all right and took whitewash quite well. A tar dado finished it off (Fig. 7). Illustration missing

These houses are still standing and still in use after nearly twenty years of Bengal.

Now as to their applicability to another climate. These walls need a sun to dry them, but I have known them built, *during the rains*, under a previously erected thatch.

They are very cool in hot weather and presumably would be warm in cold if fires could be made in them. Once the walls are made and hardened, little short of dynamite will bring them down. There are obvious drawbacks, but they cost about one-sixth or less of the cost of pukka brick-work.

C. G. M.

PART II.—PISÉ

PISÉ DE TERRE

Pisé de Terre, or the system of building with earth rammed between boards, has deservedly received more attention than Cob in recent years as being a fitter method for revival and adaptation to modern requirements. The employment of forms or shutters and a comparatively dry material is conducive to cleaner, quicker and more reliable construction than is possible with material in a mastic state.

Satisfactory work has been done in this country within the last decade by advocates of the method, all of whom have experimented by deviation from traditional lines—introducing improvements to shuttering, implements, material, or the method of ramming.

To build economically in Pisé, a suitable material must be found on the site, and all apparatus be kept as simple as efficiency will allow; any complication or unwieldiness of apparatus developed through a too zealous introduction of " improvements " would go far to destroy justification for the use of such a method at the present time.

Rapidity of erection depends principally on the ease with which the shuttering can be manipulated, and on the work being carefully thought out beforehand.

To build soundly, the foundation must be solid and the walls protected from damp above and below, and from rain and accidental water on the face. Provision should also be made to guard against vermin. These requirements resolve themselves into a study of materials, tools, methods of construction and protection.

Materials

In Henry Holland's very complete report on Pisé de Terre in " Communications to the Board of Agriculture," 1797, extracts are given from a French author, François Cointeraux, who

described the method as carried out in the province of Lyons for centuries. He says—

> "The possibility of raising the walls of houses two or even three stories high, with earth only, which will sustain floors loaded with the heaviest weights, and of building the largest manufactories in this manner may astonish everyone who has not been an eye witness of such things . . . . ."

The choice of material is described at great length. He gives all earths in general as fit for use, "when they have not the lightness of poor lands nor the stiffness of clay." Brick earths, liable to crack when used alone, he suggests could be mixed with certain others to advantage. The most suitable in his opinion was a "strong" earth with an admixture of small gravel.

A number of commonsense tests to ascertain whether earth is suitable for rammed work are explained in detail, for example, ramming the earth, freed from large stones and vegetable matter, in layers, in a tub with splayed sides, reversing the tub when full, removing it and studying the behaviour of the compressed earth. If the specimen continues without cracking or crumbling and increases daily in density and compactness as its natural moisture decreases, the earth may be taken as fit for building purposes.

An earth mixture that does not contain an aggregate forming the body, together with a matrix or binding agent, is useless : pure clay and pure sand are alike unsuitable, but a clay stabilised with carbonate of lime, or with a high content of sand, is as good as anything for the work. Rotten stone taken from the layer where it is weathering into soil makes an excellent pisé wall, whereas clean, broken, or chipped stone could only be used with a cementing material.

An excess of either of the two essential components is likely to result in failure. Too much aggregate means crumbling and, if the binding agent is clay, too much matrix, the development of cracks through excessive shrinkage whilst the walls are drying.

Generally speaking anything that will bind into a good clean footpath for wet or dry weather shows promise of being a reliable material. It is desirable, however, that before work is commenced a sample of the earth to be used should be rammed and tested and a liberal factor of safety allowed. "The British Clayworker" (15th November 1920), gave a crushing strength of 280 lbs. per sq. inch (18 tons per sq. foot) as a minimum to work to. This figure at first sight appears high for ordinary work, but with a judicious use of materials should not be difficult to attain. A sample of Wealden clay too stiff for use alone, when mixed with 25 per cent. fine clinker possessed a crushing strength of as much as 32 tons per sq. ft. (*See also* Appendix I.)

A German writer on the subject recommends a mixture consisting of—

1 part—stiff clay.
1 part—sharp sand.
2 parts—broken stone (the pieces being the size of a small apple).

Fig. 8.—Ramming of Chalk-cement Walls at Amesbury.

He gives furnace slag or clinker as an alternative for stone, and adds that no porous organic matter should be tolerated as it renders the wall hygroscopic. He suggests, however, that straw, cut to 3″ or 4″ lengths, one eighth the volume of the mixture, if added would tend to strengthen the mixture and prevent cracks.

Of several small wall sections of various materials, erected at the Experimental Station of the Building Research Board, one of mâchefer and lime mixed and two of clay mixed with clinker have proved the most satisfactory. A hut was also built at the Station, the walls of which were composed simply of rammed "dirty" ballast; they were treated with oil of tar sprayed on to the surface, and have stood surprisingly well.

In the Colonies ant-heap mixed with sand and soil in equal quantities has proved reliable, and where clinker is available a mixture of three parts clinker, sieved free from fine dust, to two of ant-heap is recommended.

The walls of two of the five experimental cottages erected at Amesbury by the Department were of chalk pisé. In one case chalky gravel was well mixed by hand with 30 per cent. fine soil, no water being added ; in the other, the follow ing specification by Mr. A. Alban H. Scott was worked to—

> "The chalk after digging will be broken to pass a $1\frac{1}{2}''$ mesh. It will then be mixed dry, on a boarded platform, with $\frac{1}{20}$th of its weight of Portland Cement, by turning over at least three times, as in concrete mixing and none of the mixture must be allowed to stand for more than 30 minutes before using."

Fig. 8 shows this wall being rammed. The walling of both cottages so far has stood excellently.

The instructions for the chalk-cement mixture were issued after observation of an experimental wall built by Mr. Scott at Basingstoke. The wall consisted of six sections, each 4 ft. by 5 ft., rammed between boards. Their composition was as follows :—

Section 1.—Made of pure chalk.

Section 2.—10 parts of chalk to 1 of Portland cement (mixed dry).

Section 3.—Made of chalk sprinkled with Lillington's "Metalo" liquid (1 part liquid to 10 of water sprinkled on during ramming—about 1 gallon to the section).

Section 4.—10 parts chalk to 1 of Blue Lias lime sprinkled before mixing with about 1 gallon of same liquid.

Section 5.—20 parts chalk to 1 of Portland cement (mixed dry).

Section 6.—Chalk mixed with short straw.

As was to be expected, section 2 proved the best, having a uniformly hard surface, a sharply defined outline, and showing no tendency to crumble. Sections 4 and 5 were next in order of soundness.

Section 3 showed signs of shrinkage, 6 showed fair consolidation and was slightly better than 1, the poorest part of the wall with a marked tendency to crumble and possessing no really hard bit of surface.

In a house at Prince's Risborough, Mr. T. G. Davidson has employed composite walling with success. Chalk and cement in the proportion of 6 to 1, and plain chalk were used. The chalk-cement was laid against the shutters with a spade so that it formed the wall faces. It was gauged with a weak solution of sodium silicate instead of water, and this has resulted in a dense wall with an excellent surface which needs no covering coat. It was found, however, that the setting of the cement was accelerated to an inconvenient extent by the silicate, and that it was better to gauge the mixture with water and apply the silicate solution to the face of the finished wall. The two outer quarters of the wall only consist of chalk-cement (the rest is of plain chalk) so that the cement is used economically and disposed to the best advantage. The special method of ramming is shown in Fig. 10.

Weak concrete mixtures, rammed semi-dry between shutters have certainly formed most successful pisé walls. A description of so-called "Chinese concrete" in "Lime Mortar and Cement," by W. N. Dibdin, indicates a good method for employing such a material. A mixture of one part lime and two parts sand, gravel, shingle or sand building débris and earth, is rammed in 6″ layers, water being sprinkled over the surface of each layer after ramming; the surface only is moistened. A high boundary wall at Macao built in this way is said to have stood for 250 years and to be still in splendid condition.

"Lyonese concrete" was much used for pisé work before the war in the regions of Lyons and Forez. It was a mixture of mâchefer (clinkers) and lime. The clinkers were crushed to pass a 2″ sieve. From 300 to 400 lbs. of hydraulic lime were used to one cubic yard of clinkers. Mixing was done by hand or in a concrete mixer, but the absolute minimum of water was used.

Correct condition as to moisture in the material before ramming is most important. If too dry it will not cohere, and if too wet cracks will develop while drying. It should be just damp enough to consolidate satisfactorily under the ramming. Excess of moisture causes the soil to shake in the shutters and rise in parts where the rammer is not being applied. Weighing tests have indicated that the amount of moisture should be about one eighth of the total weight. Many suitable soils, even when dug in a dry season and exposed for some days to the air, contain a much greater natural moisture content than this. As far as ultimate strength is concerned results have proved that it is better to err with a slight excess rather than a deficiency of moisture.

Tools and Methods

Sets of shuttering and rammers comprise the only special apparatus required.

Of rammers there are various patterns (Figs. 9, 10 and 13). At Amesbury the flat rammer (Fig. 9) tended to "case harden" the surface and the wood rammer to pick up the material; the small heart-shaped iron rammer proved generally the most satisfactory. The weight of the rammer should be between 7 and 12 lbs.

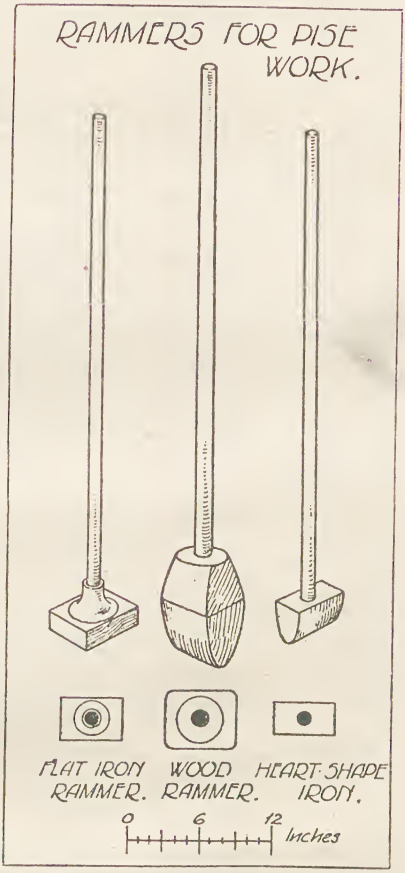

Fig. 9.

Shuttering, or the boxing in which the earth is rammed, should be easy to handle, place into position, and shift into a new position. It should be durable and rigid enough to withstand a considerable side thrust during ramming. If buildings with more than a ground floor are contemplated, its independence of support from the ground becomes an asset. Upon the rigidity and immobility of the shuttering during ramming depends the verticality of the wall, and to a large extent the quality of its surface.

There is no need to use shutter ties that leave large holes in the wall, as those employed in the cumbersome shuttering described by Henry Holland. Iron bolts or stout wire ties serve the purpose well. Bolts of course leave small holes that have to be filled, but wire ties can be cut off and left in the wall. The removal of large ties without damaging the walls is not a simple operation owing to the great pressure on them occasioned by the ramming.

Special angle sets of shuttering are sometimes used, but with most systems there is no necessity for them. By the simple expedient of commencing a course in one of the meeting walls over the end of the course below in the other wall, the walls are toothed at their junctions. The erection of angle piers too obviates the necessity for such sets.

Figs. 10, 11 and 13 show forms of shuttering that possess many or all of the qualifications required.

Mr. T. G. Davidson's type (Fig. 10) is extremely rigid and easy to handle, and possesses the added advantage of being a climbing pattern; by withdrawing the lower pair of steel rods the sides can be turned up one course and the rods replaced through

new wire ties. The ties are very carefully made on a jig, as any inequality in lengths would allow of movement during ramming.

The shuttering recommended by the Rhodesia Resources Committee in their 1921 report is interesting in that the boxing is stiffened and held in position by detachable wooden clamps (Fig. 11).

The native shuttering of India, described in a separate note, is commendable in its simplicity, but seems a little doubtful as regards stiffness.

A form specially suitable for the erection of walls up to about 10 ft. in height is that devised by Mr. Russell, F.R.I.B.A., late Chief Architect to the Ministry of Health. Pairs of 4″ × 2″ standards, covered on three sides by $\frac{1}{16}$″ steel sheathing, are placed one on each side of the base wall, at intervals of 5 ft. Each pair is carried by a sole piece with holes into which the standards are dropped and fixed with bolts. The sole pieces, with folding wedges under, pass through holes in the base wall. The actual shutter consists of a frame built up with 4″ × 2″ timber covered on one side with rolled sheet iron or steel sheathing. The standards have bolt holes at 9″ vertical intervals and the shutters are bolted to the standards with two bolts at each end. Where shutters occur on both sides of a standard the bolts connect the standard to both shutters. Two detachable diagonal braces connect each couple of standards above the shutters and these are moved up as the wall rises. Special angle sheeting with a rounded corner, can be attached for forming wall junctions. Ties through the walls are avoided. To raise the shutters the bolts connecting them to the standards are withdrawn, the shutters tilted away from the wall and re-erected 18″ higher. They have a grip of 3″ on the wall already built. This shuttering was used for the walls of the before-mentioned hut at the Experimental Station.

Sets of shutters are usually about 10 ft. or 12 ft. in length. Special short sets are found handy for returns and short pieces of walling. A set of which the depth only allows 12″ of wall to be rammed without its removal and re-erection, needs to be especially designed for speed in these operations. There seems little doubt, however, that a well designed 12″ course shutter will take less than one third of the time required to dismantle and set up a shutter giving a course depth of 36″.

The general method of procedure varies little once materials and shuttering have been decided upon.

Holland translates a detailed account of the work as carried out in the 18th century. After instructions concerning the erection of the mould over one angle on the base wall, he informs us :—

> "A workman should be placed in each of the three divisions of the mould, the best workman being placed at the angle. He is to direct the work of the other two, and by occasionally applying a plumb rule, to take care that the mould does not swerve from its upright position. The

Fig. 10.

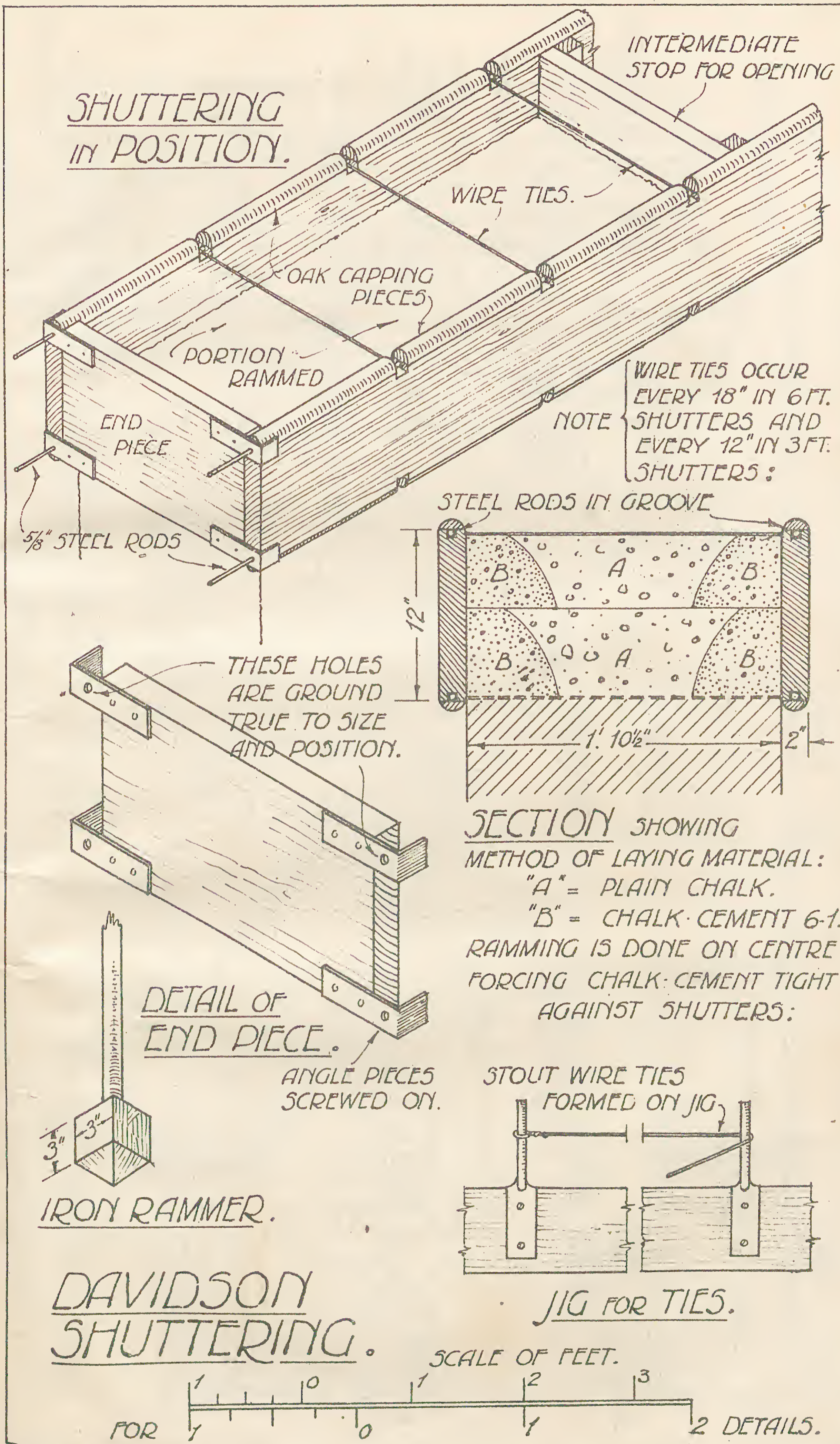

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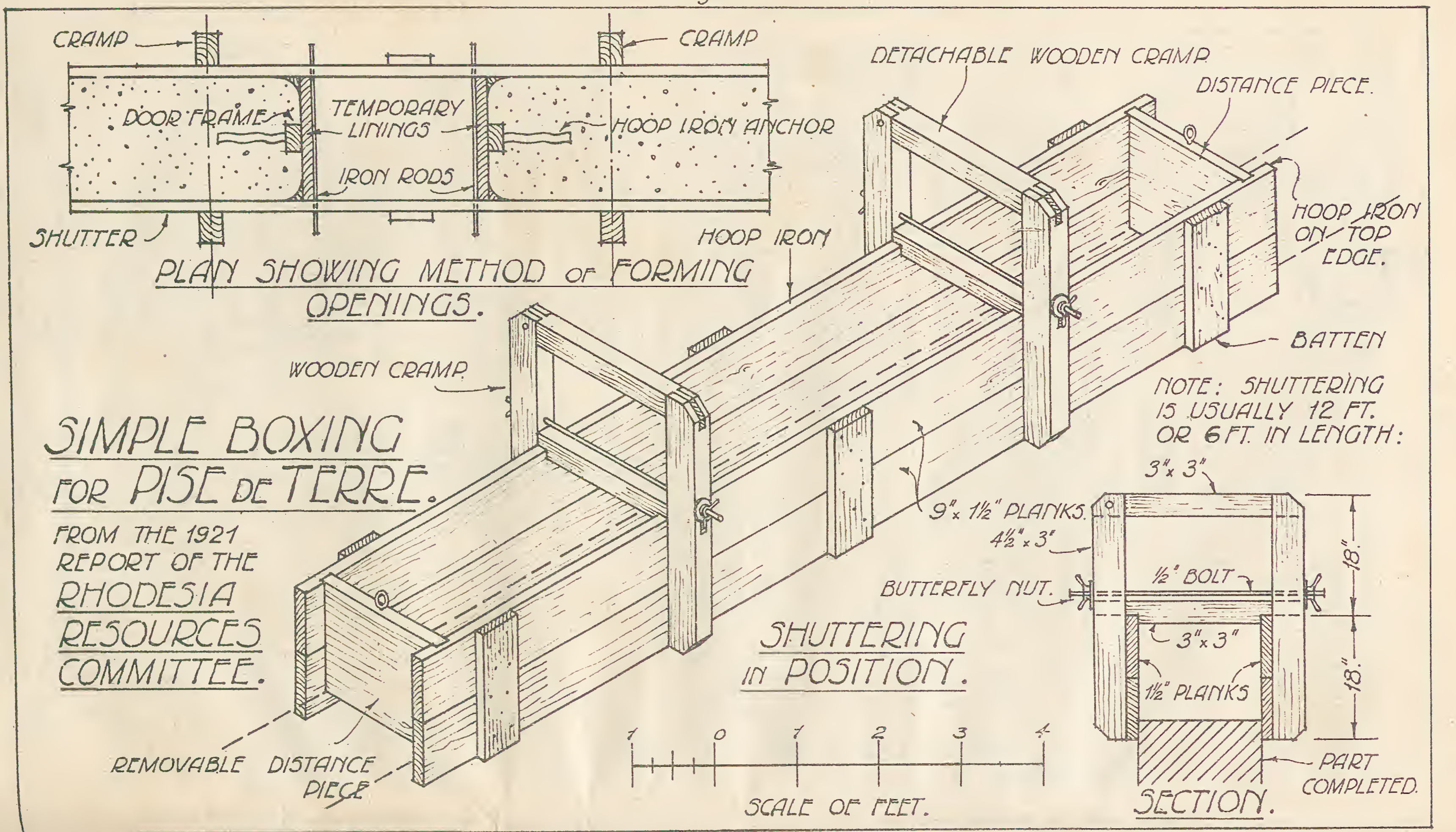
Fig. II.


CRAMP
CRAMP
DOOR FRAME
TEMPORARY LININGS
HOOP IRON ANCHOR
IRON RODS
SHUTTER
PLAN SHOWING METHOD OF FORMING OPENINGS.
DETACHABLE WOODEN CRAMP
DISTANCE PIECE.
HOOP IRON
HOOP IRON ON TOP EDGE.
BATTEN
WOODEN CRAMP
SIMPLE BOXING FOR PISE DE TERRE.
FROM THE 1921 REPORT OF THE RHODESIA RESOURCES COMMITTEE.
NOTE: SHUTTERING IS USUALLY 12 FT. OR 6 FT. IN LENGTH:
3" x 3"
9" x 1½" PLANKS.
4½" x 3"
½" BOLT
BUTTERFLY NUT.
18"
18"
3" x 3"
1½" PLANKS
SHUTTERING IN POSITION.
REMOVABLE DISTANCE PIECE
1 0 1 2 3 4
SCALE OF FEET.
PART COMPLETED.
SECTION.

labourers who dig and prepare the earth must give it in small quantities to the workmen in the mould, who after having spread it with their feet, begin to press it with the rammer. They must only receive at a time so much as will cover the bottom of the mould to the thickness of 3 or 4 inches. The first strokes of the rammer should be given close to the sides of the mould but they must afterwards be applied to every other part of the surface; the men should cross their strokes so that the earth may be pressed in every direction. . . . Care must be taken that no fresh earth is received into the mould till the first layer is well beaten, which may be ascertained by striking it with a rammer; the stroke should leave hardly any print on the place. They must proceed in this manner to ram in layer after layer, till the whole mould is full . . . . ."

When the mould was full and the ramming completed it was dismantled and re-erected a stage further along the wall. The earth was so rammed in the first position that it left a splayed end on which to ram the near part of the second section. All the joints between the sections were thus splayed. The course was about 2′ 6″ in height. When the first course was completed all round the building, the second was commenced where the first left off so that in each successive course the work proceeded in a contrary direction to that of the preceding. It is stated that "there is no reason to fear overcharging the first course with the second though but just laid, for three courses may be laid without danger in one day."

In modern work it is usual to allow about 3 hours to elapse before superimposing another course. There is the same necessity for splayed joints and for "breaking joint" in successive courses, as in building with concrete *in situ*.

The ramming needs to be rapid and equable; great pressure is not desirable, and for this reason native children are often employed on this work in South Africa.

The employment of mechanical rammers makes for speedy erection and with them it is often possible to make a sound wall with material that could not be adequately consolidated by hand ramming. Nevertheless their use drags costly plant and skilled labour into the picture. A small compressor for ramming power only, with one pair of pneumatic rammers, would cost something approaching 200*l*. Considering this outlay, together with the cost of running and the wages of one skilled operator and two semi-skilled men, and comparing with the cost of three unskilled men, hand-ramming over a longer period, it seems probable that, for anything less than a fairly large group of houses, no saving would result. Certainly the outlay would not have been justified in any of the more or less isolated examples of pisé de terre erected in England in recent years. The use of pneumatic "sand rammers" operated by a larger air compressor was advocated in a recent American trade journal. It was suggested that a plant consisting of a compressor, cement gun and pneumatic rammers

should be used for house erection, the gun being used for coating the rammed walls. The approximate cost of this plant would, at the time, have been—

Cement Gun and "Imperial" portable compressor, 1,500*l.*

Sand rammers per pair, 60*l.*

The house shown in the frontispiece was designed and built by Mr. B. G. Gaymer, A.R.I.B.A., of North Walsham, after various experiments with pisé on a lesser scale. The walling material, a loamy clay, was taken from the field in which the house stands. The base wall is of concrete. The floors are carried on a thin course of concrete and a capping course of concrete takes the roof plate. A dry concrete mix was deposited against all jamb linings and rammed with the earth. This ensured a good hard face to the jambs when the linings were removed. The roof and most of the floor joists were made from Handley Page aeroplane spars—surplus war stock. The thatch is of Norfolk reeds and 12″ thick. The photograph was taken immediately after the gale of 6th November, the worst experienced in the district for 25 years and to which the house was fully exposed.

Largely from the experience gained during the erection of this house and a bungalow at Paston, Mr. B. P. Gaymer and Mr. Gaymer, Senior, of Messrs. Cornish & Gaymer, have developed and patented a panel system of pisé construction. Briefly, it may be described as follows: Concrete block piers are put up. on a wide foundation wall at regular intervals round the building. One panel, about 14′ × 8′, is filled and completed, from base to eaves, with all required openings, before another is commenced. It is capped at the top with a course of cement concrete. The shuttering is peculiar to the method, the earth being rammed between planks placed on top of one another as the work rises and held against the piers and intermediately by frames composed of sills, resting on the projecting foundation wall, a head and four uprights. The frames are fixed the correct distance apart by cross bolts at the head of the uprights and by climbing distance pieces which can be raised on the uprights as the work proceeds. When the panel is completely rammed it has been entirely enclosed by planking, to remove which it is only necessary to unfasten and drop the frames; no ties of any sort pierce the wall. The method greatly facilitates construction in bad weather, and with the piers acting as guides there is not the usual difficulty in getting a truly vertical wall with unskilled workmen. It is claimed that three men can complete one panel in two days.

Special Construction Details

In old work chimney breasts and stacks were constructed of brick or stone, but in some new work they have been built successfully in pisé, the earth being rammed around drainpipe flues. This has necessitated a complicated adaptation of shuttering, liable to confuse unskilled labour and interrupt the smooth running of the work.

Openings should be blocked out in the forms as the work proceeds either by inserting temporary wood jambs or by building in permanent jambs and lintels of wood or pre-cast concrete. These should be well braced to withstand pressure during the ramming. The practice of cutting out openings after the walls were finished obtained in old work, and this is interesting as it can be still resorted to if alterations are required. Mr. Gaymer obtains an effective deep, splayed jamb by inserting his window and door frames tight against the shutters on the outside of the wall. On the back of the vertical sides of the frames are screwed temporary fillets and temporary jamb linings are jammed against these and the inner shuttering on the skew. They are removed by unfixing the fillets. By making the head of the frames segmental it is possible to employ a relieving arch of concrete blocks.

The comparative thickness of the walls calls for suitably designed lintels. Those designed for the Amesbury cottages and the ones described in the note on pisé de terre in Belgium serve their purpose well. Where the jambs are in pisé, a long bearing for the lintel should be given and extra support can be obtained by carrying the ends on cross bearers bedded in.

External angles should be rounded off. The use of specially designed angle piers in some work should be noted. Ordinary brick or masonry quoins are not advisable. The shrinkage of many earths from them might be appreciable and difficult to make good. If it is necessary to use different material in such a position, a place should be allowed for it during the construction of the walling, and after the earth has properly dried out, brickwork, &c. can be built in.

If the material is of poor quality, reinforcement may be deemed necessary, especially at the angles. The traditional practice of reinforcing wall junctions by embedding planks crossing one another at the corner in the pisé can be superseded by laying wire-netting or other metal reinforcement between the courses. Barbed wire laid zig-zag in the walls and in strands crossing one another at the angles is a method approved.

The thickness of the walls depends on the quality of the material. For ordinary earth pisé the ground floor external walling may be anything from 14″ to 24″ thick. Some mixtures containing a cementing material would permit of the thickness being decreased below 14″.

For internal partitions, if the material is inferior and floor space precious, the use of some other material than pisé may be preferable, but partitions from 9″ to 12″ thick have been made with good earth. In the North Walsham house previously described the thickness was reduced to 6″, and a particularly strong partition obtained by ramming the earth between studs about 2′ 6″ apart. A triangular fillet nailed down the centre of the sides of the studs keys the earth to them. Planks clamped to the studs served as forms. Whatever the structure, the internal walls should be taken into a slot purposely provided on

the inside of the walls, or bonded to them in some other way. It has been found in recent work that the ramming of an internal partition up to a completed external wall has resulted in damage to the latter. Temporary strutting against the external wall during such a proceeding is essential.

If the external walls are thinned down at first floor level the floors can be carried on a plate in the usual way, but if the same thickness is maintained up to the eaves a thin course of concrete, projecting sufficiently to take the ends of the joists, will serve to support the floor.

Protection

The great enemy of pisé walls is water; once allowed to penetrate them its effects are disastrous.

Some failures in new work have been due to sudden rainstorms catching the walls unprotected during erection, and the top surface should always be covered when it is not being worked on. In this country the work need not be restricted to a dry season. Good walls have been put up in winter, but the difficulty of procuring soil which is not too wet, and the extra covering precautions necessary during a wet season naturally impede the work.

A good sound base wall, with a damp-proof course, and carried high enough above ground level to prevent rain splashes and surface water from reaching the pisé, will afford protection from below. In addition damp-proof courses should be laid at the top of the wall under the roof plate, and under all sills. Eaves should have a good overhang. The effect of rain beating against the natural surface of earth walls is not so damaging as one might suppose. Pisé walls in England have stood severe winters with no surface protection and they have remained undamaged in India and South Africa through tropical downpours though here it must be remembered they had probably been previously sun-baked to an extent beyond possibility in a temperate climate. It is generally admitted that at any rate for better class work, some form of covering or finish is advisable.

Rendering and plastering have been much used and are fairly certain to give rise to expenditure on maintenance as they do when used with other backings. Inequalities of expansion and contraction in the earth and covering are likely to cause cracks, and, where exposed to the weather, wet will enter and eventually cause the coating to fall off in patches; the lime or cement used would probably be better employed in the wall itself. In some new work recently inspected a thin coating of cement slurry showed a decided inclination to flake off, and it seems evident that anything which tends to form a separate rigid casing should be avoided.

If rendering or plastering is to be carried out, the walls should be carefully brushed free of loose earth, some form of key provided, and the surface evenly damped over.

In this connection an extract from Vol. 1 of "Professional Papers of the Madras Engineers," page 31, is interesting.

> "For preserving the surface . . . . the latest mode adopted is to place on the edge of each layer of earth in contact with the plank sides, rows of pieces of tiliff (broken tiles) to be embedded 3″ or 4″ in the wall and along with these to a somewhat less depth in the wall, a mixture of lime, soorkhi (brick dust) and broken brick. This is slightly moistened and being rammed similarly to the rest of the work becomes when finished a pukka facing to the wall. This will more readily than earthen pisé receive plaster . . . . ."

The soundest method appears to be treatment with a liquid waterproofing mixture, such as a solution of silicate of soda, a lime wash made with boiling water, hot coal tar, or a solution of bitumen, resin, or paraffin wax, in light oils. Such coats, which all possess some penetrative power, are better sprayed than brushed on. The selection of a colour finish to cover satisfactorily some of the foregoing presents difficulties. Special paints have been made up and used, but their lasting effectiveness has yet to be proved.

There appears to be no reason why a pisé house with good dense walls provided with a vermin proof base, and kept in good repair, should be more susceptible to attack from vermin than one of some other form of construction. Liability to attack is largely avoidable by cleanliness on the part of the inmates.

Precautionary measures adopted by some consist of treatment of the earth before ramming with chemicals, or the admixture of powdered glass in the lowest course of the wall. To guard against the ingress of white ants, where such pests are experienced, carbolineum or other ant preventive should be mixed with the earth of the first course. The use of ashes in the mixture is supposed to be a preventive but this is not infallible.

General

There is ample proof that thoroughly sound and durable walls were constructed on the most ancient of pisé de terre systems.

Pliny in his "Natural History" comments on the strength and lasting qualities of "formoceon" walls, "moulded, rather than built, by enclosing earth within a frame of boards."

Failures were no doubt common, but were due in the great majority of cases to causes that could be avoided in modern work. Those who have followed the lead of Mr. St. Loe Strachey, the revivalist of the method in England, and whose work is described in "Cottage Building in Cob, Pisé Chalk and Clay," by Mr. Clough Williams-Ellis, have progressed a long way towards the elimination of such causes. With the more efficient types of shuttering now available there is no real restriction of plan. There are perhaps more limitations to such a method than to one employing a small unit of construction, but any good straightforward plan should be workable.

For maintaining an equable temperature within, pisé walls are hard to beat; they make the most comfortable of dwellings in winter or summer, and excellent stores for produce or materials affected by excessive heat or cold.

Costs depend so much on local conditions that they are hardly worth giving in detail. Mr. Davidson claims that his composite walls, 1′ 10½″ thick, at Prince's Risborough were 35 per cent. cheaper than 11″ hollow brick walls would have been. In another cottage of earthen pisé, the saving effected was 80 per cent. on the cost in brick work. Mr. Gaymer estimated that the house shown in the frontispiece was erected for two-thirds the cost of one similar in brick.

The fact remains that if the price of bricks, labour and transport settles to anything like the pre-war value, there will be no appreciable economy in using pisé except where the cost of walling bulks largely in the total cost of the building, or in particularly isolated situations.

From time immemorial "raw earth" construction, in various forms, has been the natural solution of the housing problem wherever the lack of other material, or the skill necessary to employ such material when at hand, occurred. There are some who contend, in the light of recent experience, that once a better understanding of the true factor of strength and the best surface treatment of the various usable earths is obtained, building with "raw earth" will stand comparison with other construction even where no saving accrues, and where alternative material and the skilled labour to use it are available.

P. W. B.

"LE TERRADAMENTE" SYSTEM IN BELGIUM

The system of pisé construction described in the following note was employed in the first instance by Messrs. Holland Hannen and Cubitts, at Ypres, in 1920.

After several months of experimental work by Mr. J. D. Eshelby, the firm's representative in Belgium, the method was evolved and placed before the then Royal High Commissioner of Ypres, who immediately realised its possibilities as a means towards a solution of the building problem in the devastated area.

Little or no skilled labour was required and no material for walling other than the debris and mud to be found all around. At that time, although the market price of bricks was only about 75 francs per 1,000, difficulties of transport were such that their cost on the site would have worked out at something like 175 francs per 1,000. The Belgian brick, of course, is small, 1,000 going to the cubic yard. The usefulness of a "site material" method in such circumstances is apparent.

A site was allocated near the remains of the Cathedral, and on this a row of eleven dwellings was completed, except for doors

Fig. 12.—"Le Terradamente" Houses at Schaerbeek.

and windows, within two months, at a cost of about 40,000 francs. One or two detached houses were also erected; one of them possessed a first floor and was inhabited within ten weeks of its commencement. These pisé houses, surrounded on all sides by makeshift yet costly "temporary dwellings," have proved satisfactory in every respect.

So far no extensive building scheme has been arranged on the system, and with Messrs. Holland, Hannen and Cubitt's agreement, Mr. Eshelby has formed a small company under the name of "Le Terradamente," the system being protected under the names "Eshelby, Holoffe, Marchal." This company has put up two blocks of cottages in the Avenue Paul Deschanel at Schaerbeek (Fig. 12), and is now completing a detached house at Uccle. Work is also being carried out in the Belgian Congo.

By the courtesy of Mr. Eshelby I was allowed to inspect the buildings at Uccle and Schaerbeek.

Material

"Le Terradamente" houses are described as "constructions économiques en aggloméré de terre imperméable." A loamy clay or brick earth is preferred. In the case of a heavy clay, if dug in the autumn and spread over the site, the action of the air, rain and frost during the winter renders it reliable for the work.

The walling material for the row of cottages at Ypres consisted of soil from the Bishop's garden. The site was first covered with a concrete raft of brick débris and cement. At Schaerbeek clay from the site was used, and at Uccle, a similar moderately strong clay containing a fine sand.

The clay, after being dug, was thrown hard through a screen. It was then spread out and sprinkled with from one-tenth to one-sixth its volume of hydraulic lime pulverised, and cheap and easily obtainable chemicals, to prevent organic growth and as a protection against vermin. The prepared earth, well mixed with a rake, was again screened before ramming. The screening breaks up and aerates the soil, and at the same time rids it of large stones, roots, &c. The treatment naturally varies a little with different earths. The soil is generally quite damp enough for the work, but during the recent drought it was found necessary to sprinkle it lightly with a little water—just enough to cause the soil to bind when pressed in the hand.

The impermeability of the walling is ensured by treatment with a patent liquid consisting of 2 parts of crude benzol and 1 part of bitumen previously dissolved in benzoline, with a little resin and quicklime added. This impregnating solution is applied on the exterior of the wall after the shutters have been removed, and may be sprayed or brushed on. It penetrates well into the wall and has a remarkable hardening effect. Surfaces that can easily be scraped away with a finger nail possess a face like stone after treatment. A litre of the liquid covers about

10 square metres and the present price is 1·80 francs per litre. It leaves the wall a nigger brown colour.

Apparatus

The patented shuttering is simple and can be dismantled and re-erected in five minutes (Fig. 13).

Each side is about 10′ by 3′ and consists of 1″ tongued and grooved boarding held together by four 6″ × 2″ vertical ledgers. At one end, the edge of a ledger projects 2″ beyond the ends of the boards, and at the other the boards project 2″ beyond the ledger. This allows the sections to interlock. A wrought iron strap is bolted to the top of each ledger and these project to take ¾″ bolts, which tie the sides of the shuttering together. These top bolts pass through pieces of tubing which act as distance pieces. The bottom bolts, which rest on the wall already built and support the shuttering, pass through the ledgers about 2′ 6″ below the distance pieces. In the earlier shuttering the ledgers were carried up to take the top bolts, and the straps were not employed. Before using, the inside surfaces of the shuttering are given a coat of the bitumen solution.

The rammer differs from most others in use. It consists of an inverted-wedge-shaped piece of iron. The bottom is flat and 2¾″ square. The overall length of the tool is about 3′ 6″. Another similar but slightly larger one is sometimes employed.

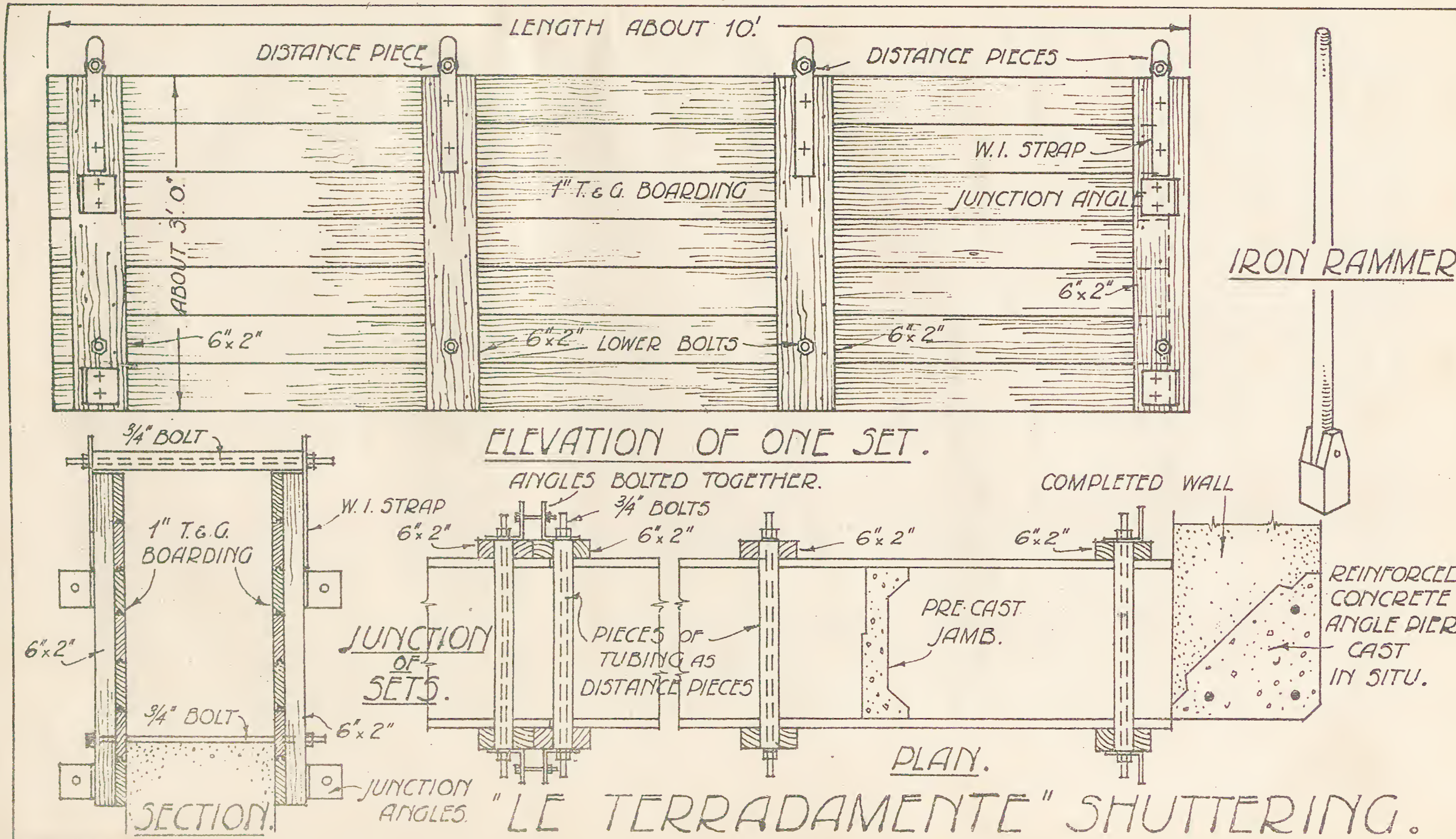
Method

A low concrete, brick or stone foundation wall is first laid to about 12″ above ground level, and at each corner of the building a triangular reinforced concrete pier is formed. The plinth wall is provided with a damp course, usually of tarred felt. The pier is cast *in situ* with two special forms bolted together. The piers, whilst forming strong angles, act as guides for the shuttering and are so designed that the continuity of the pisé walls is not interrupted, and the straight joint at the junction of the pisé and concrete is cut down to a minimum. External walls are made from 14″ to 16″ and internal walls about 10″ thick; by simply changing the bolts and distance pieces, walls of any reasonable thickness can be constructed.

The concrete for the angle piers, and for the jambs and lintels described below is usually made up from ·800 cubic metres of gravel or quarry chippings, ·400 cubic metres of sand to 350 kilos of first quality cement.

It is usual to employ three men ramming in the shuttering, with three more digging, preparing and throwing the earth to them. Six men can ram about 6 cubic metres per day of eight hours up to a height of 10 ft. above ground level, and above this about 4 cubic metres. The earth is rammed in layers about 4″ deep with quick, firm strokes. No violence is necessary, but particular attention is paid to the ramming on the edges of the wall.

Fig. 13.



"LE TERRADAMENTE" SHUTTERING.

26061/579/044. 750. 4/29. C & R. PP. 641

If the building has two floors, a string course of concrete 6″ thick is laid at first floor level, and more angle piers can be erected on this. This course also carries the floor. In the Schaerbeek cottages the upper floor rooms are partly in the roof, and in this case the angle piers are carried straight up from base-wall to eaves.

Concrete door and window jambs, of the channel section shown in the drawing (Fig. 13), are pre-cast, and fixed in the shuttering and the earth is rammed up to them. The heads are usually segmental, but of the same section as the jambs. Sills are inserted after the wall is completed. For door openings in internal walls, the door linings are placed in position in the shuttering and gradually built in. The lintels, of wood at least 9″ × 3″, bear upon the finished wall as soon as it has reached the required height. The lintels require strutting whilst the earth is being rammed above.

At the intersection of internal and external walls, a key slot is left in the outside wall. This is obtained by placing inside the form a 9″ × 2″ board with bevelled edges, to facilitate removal.

Where water pipes pass through the earth walls they are packed around with cement to obviate damage from leakage.

The face of the wall when the shutters are removed is excellent. The holes left by the lower bolts are carefully filled with earth rammed in. The walls at Schaerbeek and Uccle have been given a masonry finish by cutting imitation joints with a special tool. This is a piece of wood about 9″ × 6″ × 1″, having four narrow steel blades, set behind one another, along one edge. The blades, which are inserted diagonally into the wood, project sufficiently to make a groove about ¼″ deep. To obtain a texture resembling that of stone the walls are roughened slightly by rubbing with a brick or pumice stone. These operations, of course, are carried out before impregnation and painting. The concrete angle piers in the house at Uccle are hacked and finished with rusticated quoins in cement and sand.

Chimney stacks and breasts are in brickwork. The roofs are of ordinary construction but have a good eaves projection.

After the exterior of the pisé work has been impregnated with the bitumen solution it is painted. Oil paint was found to be unsatisfactory, and a paint made from Lithopone, benzoline and resin is now used.

All internal wall faces are left untouched for about two months in dry weather and three or four in wet. When the walls have thoroughly dried out they can be coated with size mixed with benzoline, and then colour-washed, painted or papered. For better work skimming with white plaster, about ⅛″ thick, is being tried. So far it is satisfactory.

General

There are two blocks of four cottages in the Avenue Paul Deschanel at Schaerbeek. Each cottage contains a living room,

kitchen and two bedrooms. A common wash house divides each block into two. They were constructed under the worst possible weather conditions, and their cost was about 47,000 francs.

The walls seem thoroughly sound and true. The rendering on the concrete piers is falling off in one or two places, but this is obviously due to the surface of the piers not having been hacked, as the surface where exposed is quite smooth. The oil paint used on these cottages is discoloured in places by the bitumen underneath and is showing some signs of peeling.

The detached house at Uccle has a cellar, ground and first floors and rooms in the roof. It is intended to be a good class house, and it is estimated that its cost, when completed with drainage, will be about 42,000 francs. Here I was able to see the wall as left by the mould. It was quite smooth in surface and extremely well consolidated. The walls were perfectly vertical and the junctions between concrete and pisé excellent. Where the impregnation had been completed the surface was extremely hard. The paint still further hardens it, and when both impregnated and painted it is difficult even to scratch.

The only cracks seen in any of the walls were very slight and occurred under the ends of the window sills in the unfinished work. These, due to greater settlement between the window openings, and probably inevitable, are made good when the settlement is complete.

The number of men employed per day on the house at Uccle averaged about seven, and the foreman had had no previous experience of pisé work. The labour available is generally of a low order, but it is no uncommon thing for a man to work 60 hours per week. Writing of the work at Ypres in a letter to the *Spectator* (28th August 1920), Mr. Eshelby said—". . . . of the 5,000 that work at Ypres each day, 99 per cent. average four hours a day train travelling, and they are a 'Hobson's choice'; equally incompetent and untrained, they offer themselves as bricklayers, joiners or plumbers as the need arises. . . ."

The successful results which have been accomplished, in spite of the extremely poor quality of labour available, must be attributed largely to the simplicity of the method.

15th September 1921. P. W. B.

PISÉ WALLING IN THE SIMLA HILLS

The forms described have always been used by the natives of the Simla Hills district for their own houses and were copied with very little modification for the buildings constructed for the Simla hydro-electric scheme in 1910.

The sides of each form were of two boards $1\frac{1}{2}''$ thick, usually $9'$ long by $1'$ high and were held together by four flat ties of bamboo about $2''$ wide by $\frac{1}{2}''$ thick, which were passed through holes near the corners of the two boards, the latter being held in

place by bamboo cotters driven through slots near the ends of the ties.

In moulding the first course, the boards were laid on the ground, and in subsequent courses the weight of the form was taken by the lower cross ties which rested on the top of the wall already built.

The material was used sufficiently dry to admit of the form being removed almost as soon as the ramming was done, and no difficulty was found in knocking the cross ties out of the walls.

In this way one form could be used several times in the same day, and no shoring or side strutting was ever necessary ; indeed a small house was often built in a few weeks with only one of these simple forms and a couple of cross boards jammed in between the sides to form door and window openings.

The walls were from $1\frac{1}{4}'$ to $2'$ thick and were left in the rough for temporary store rooms, &c., but were plastered with a mixture of chopped straw and clay served with a cowdung solution and lime-washed inside and out in temporary buildings for the construction staff.

Permanent buildings had interiors plastered as above, but were lime-plastered externally with burnt clay and white lime mortar, which, before setting, was given a coat of rough cast (white lime and gravel).

All rooms had eaves projecting $1\frac{1}{2}'$ and these walls have lasted well in spite of the heavy annual rainfall—some 90 inches.

A. R. V. A.

COMPRESSION TESTS ON PISÉ BLOCKS

RESULTS OBTAINED AT THE EXPERIMENTAL STATION OF THE BUILDING RESEARCH BOARD, EAST ACTON, ON NOVEMBER 8th, 1921

No.	Date of Ramming.	Composition of Sample.	Dimensions.	Weight.		Approximate Weight per cubic ft.	Crushing Load.	Crushing Load per sq. ft.
		CLAY-BREEZE BLOCKS.	L. × B. × H.	lbs.	ozs.	lbs.	Tons.	Tons.
1	18.12.20	London clay and breeze (4 to 1)— Coated with oil of tar	$5\frac{3}{4}'' \times 5\frac{3}{4}'' \times 5\frac{3}{4}''$	12	$5\frac{1}{2}$	111	4·45	19·4
2	do.	do. do.	$5\frac{3}{4}'' \times 5\frac{3}{4}'' \times 5\frac{1}{2}''$	11	13	116	5·15	22·9
3	do.	Coated with lime wash	$5\frac{3}{4}'' \times 5\frac{3}{4}'' \times 6''$	12	0	105	4·15	18·1
4	do.	Uncoated - - -	$5\frac{3}{4}'' \times 5\frac{3}{4}'' \times 5\frac{3}{4}''$	12	6	115	4·80	20·9
5	do.	do. - - -	$6'' \times 6'' \times 6''$	11	14	95	3·85	15·4
6	do.	do. - - -	$5\frac{3}{4}'' \times 5\frac{3}{4}'' \times 6''$	11	15	104	4·45	19·4
7	22.12.20	London clay and breeze (6 to 1)— Uncoated - - -	$5\frac{3}{4}'' \times 6'' \times 5\frac{1}{2}''$	12	2	110	4·42	18·4
8	do.	do. - - -	$5\frac{1}{2}'' \times 5\frac{1}{2}'' \times 5\frac{1}{2}''$	11	12	121	5·01	23·9
9	13.12.20	London clay and breeze (8 to 1)— Coated with lime wash	$6'' \times 6'' \times 6''$	12	4	98	4·55	18·2
10	do.	Uncoated - - -	$5\frac{3}{4}'' \times 5\frac{3}{4}'' \times 5\frac{1}{2}''$	12	9	120	5·42	23·7
11	20.12.20	Fletton clay and breeze (4 to 1)— Coated with oil of tar	$6'' \times 6'' \times 6''$	13	6	107	4·62	18·5
12	do.	Coated with lime wash	$6'' \times 6'' \times 5\frac{7}{8}''$	11	14	$97\frac{1}{2}$	2·15	8·6

No.	Date of Ramming.	Composition of Sample.	Dimensions.	Weight.	Approximate Weight per cubic ft.	Crushing Load.	Crushing Load per sq. ft.
13	15.12.20	Fletton clay and breeze (8 to 1)— Coated with oil of tar	6 ″ × 6 ″ × 6 ″	13 3½	105½	4·80	19·2
14	do.	Coated with lime wash	6 ″ × 6 ″ × 6 ″	13 14	111	5·80	23·2
15	do.	Uncoated - - -	6 ″ × 6 ″ × 6 ″	13 2	105	3·90	15·6
		CHALK-CEMENT BLOCKS.					
16	25. 1.21	Chalk and cement (20 to 1)— Water, 1 part - -	Top 4″ × 6″ to 6″ × 6″ × 6″	11 12	113	·70	3·5
17	2. 2.21	Waterglass, 1 part -	Top 5½″ × 5½″ to 6″ × 6″ × 6″	11 10	101½	·90	3·9
18	7. 2.21	Water, 1½ parts - -	Top 6″ × 6″ (less 2″ sq.) × 6″	11 11	97	1·80	7·6
19	20. 1.21	Waterglass, 1½ parts -	Top 4″ × 6″ to 6″ × 6″ × 6″	10 13	103	1·15	5·5
20	10. 2.21	Water, 3 parts - -	Top 6″ × 5″ to 6″ × 6″ × 6″	11 14	103½	2·10	9·2
21	17. 2.21	Waterglass, 3 parts -	Top 6″ × 5″ × to 6″ × 5¾″ × 5¾″	11 5	105	1·80	7·1
22	17. 3.21	Water, 6 parts - -	6″ × 6″ × 6″	12 10	101	3·85	15·4
23	do.	Waterglass, 6 parts -	6″ × 6″ × 6″	12 3	97½	2·95	11·8

APPENDIX II

BIBLIOGRAPHY

The following list of publications, though not embracing all the literature on the subject, may be said to include the bulk of the information available concerning "raw earth" construction, both ancient and modern. In only one or two instances is the whole of the publication devoted to the subject; the others merely contain references, letters, articles or reports relative to one or another of the various methods.

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2. "Book of the West": S. Baring Gould.
3. "Builder," Vol. V, 1847, pp. 364 and 388.
4. "Communications to the Ministry of Agriculture," 1797, Vol. 1 (Report on Pisé de Terre by Henry Holland).
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